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ABSTRACT

This study investigated the effects on student scientific efficacy after participation in the Goldstone Apple Valley Radio Telescope (GAVRT) project. In the GAVRT program, students use computers to record extremely faint radio waves collected by the telescope and analyze real data. Scientific efficacy is a type of self-knowledge a person uses to determine his or her ability to understand and work within the scientific community. An attitudinal survey was administered to all students nationwide who participated in the GAVRT program during the 2000-2001 and 2001-2002 school years and had 480 and 562 respondents respectively. The students completed a pre-survey prior to beginning the GAVRT program and then completed a follow-up survey immediately after working on the Jupiter Quest program. Between the pre- and post-surveys, students received instruction in the GAVRT curriculum and participated in operation of the radio telescope. During the 2000-2001 school year, increases in students' scientific efficacy occurred in their feelings of efficacy associated with the value they placed on the work they produced in science. During the 2001-2002 school year, the following areas of efficacy increased: students' perceived abilities to use scientific equipment, students' feelings about how other people valued their work, and students' abilities to think scientifically. (Contains 16 references.) (Author)

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The Role of the Goldstone Apple Valley Radio Telescope Project in Promoting Scientific Efficacy Among Middle and High School Students

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Abstract

This study investigated the effects on student scientific efficacy after participation in the Goldstone Apple Valley Radio Telescope (GAVRT) project. In the GAVRT program, students use computers to record extremely faint radio waves collected by the telescope and analyze real data. Scientific efficacy is a type of self-knowledge a person uses to determine his or her ability to understand and work within the scientific community. An attitudinal survey was administered to all students nationwide who participated in the GAVRT program during the 2000-2001 and 2001-2002 school years and had 480 and 562 respondents respectively. The students completed a pre-survey prior to beginning the GAVRT program and then completed a follow-up survey immediately after working on the Jupiter Quest program. Between the pre- and post-surveys, students received instruction in the GAVRT curriculum and participated in operation of the radio telescope. During the 2000-2001 school year, increases in students' scientific efficacy occurred in their feelings of efficacy associated with the value they placed on the work they produced in science. During the 2001-2002 school year, the following areas of efficacy increased: students' perceived abilities to use scientific equipment, students' feelings about how other people valued their work, and students' abilities to think scientifically.

The Role of the Goldstone Apple Valley Radio Telescope Project in Promoting Scientific Efficacy Among Middle School and High School Students

Efficacy is a type of self-knowledge that an individual uses to assess his or her personal ability to produce an intended result (Bandura, 1986; School Dictionary 3, 1993). This study is part of ongoing research to determine if students experience an increase in their scientific efficacy after involvement in collecting data as team members with scientists from the Jet Propulsion Laboratory (JPL) and NASA. This study defines scientific efficacy as an individual's perception about their ability to produce a desired effect as it relates to the principles, practices and methods of scientists. Basically, scientific efficacy is a type of self-knowledge a person uses to determine his or her ability to understand and work within the scientific community.

Students involved in this project work with mission control at the Lewis Center for Educational Research in Apple Valley, California. The GAVRT project seeks to communicate the relevancy and excitement of science to students and teachers through the use of motivational educational programs. Students use computers to record extremely faint radio waves collected by the telescope and analyze real data. Previously, anecdotal evidence indicated that the GAVRT program impacted students' attitudes about science. The Lewis Center conducts longitudinal research to identify the characteristic impacts of the GAVRT project on students across the nation.

The focus of this study is to quantify attitudinal findings that were illuminated through previous informal qualitative research. The students involved in the study participate in the GAVRT project. The GAVRT project involves thousands of student scientists across the nation in the collection and analysis of astronomical data using a 34-

meter radio telescope. These students contribute to the work of the world's foremost authorities on space science when they forward their information to NASA's Jet Propulsion Laboratory scientists in Pasadena, California. The JPL scientists use the information to expand their studies of Jupiter, Uranus, and variable quasars.

When efficacy beliefs are systematically varied in diverse causal tests, findings show that such beliefs contribute to human motivations and attainment (Bandura, 1992). Sources for efficacy beliefs among individuals are based on four main forms of influence. These include mastery experiences, vicarious experiences, social persuasion, and physiological and emotional states (Bandura, 1995). The GAVRT program is effective because it utilizes three of these forms of self-efficacy.

Vicarious experiences occur when another similar person is observed to have successfully performed an action (Bandura, 1995). The opportunity to interface with scientists provides a vicarious experience for GAVRT students. This provides a model of success for these children and enhances their belief that they also may be able to achieve success (Bandura, 1986; Schunk, 1987). Qualitative evidence suggests that the scientists serve as social models when the students converse with them. Transcribed teleconferences of such conversations indicate that the scientists frequently share personal insights about their own children or childhood.

Mastery experiences occur when an individual has repeated successes related to an action. Mastery experiences provide the most authentic evidence of a person's potential to succeed (Bandura, 1995). The GAVRT project is designed to include antenna operators and scientists who guide students through maneuvers so that mastery is attained over the course of an on-line antenna session.

Social persuasion occurs when a person is convinced by another individual that they are capable of success (Bandura, 1995). This is evidenced in the GAVRT program by the verbal support students receive from the mission control operators, JPL scientists and their classroom instructors as they perform tasks associated with the operation of the radio telescope. The relationship continues as students informally teleconference with the scientists or communicate via electronic mail. Such use of social persuasion can influences student's beliefs about their efficacy (Litt, 1988; Schunk, 1989).

Physiological and emotional sources of efficacy beliefs have not been associated with experiences in the GAVRT project. Physiological factors include heart and respiration rate, stamina, fatigue and pain. Emotional sources are based on the congruency between an individual's feelings and his or her cognitive appraisal of the situation.

Efficacy has been linked to student abilities. In general, low-ability students feel less efficacious about learning than students with high-ability. Collins (1982) found that ability is related to skillful performance, but students with high self-efficacy solved more problems correctly and elected to rework problems they missed. The mastery and social persuasion aspects associated with the GAVRT program seem to enhance the students' feelings of scientific efficacy and could provide an important link to greater overall efficacy and increased academic performance.

GAVRT students interact with a wide variety of scientists and educators in the GAVRT program and the role of these adults in student scientific efficacy should be considered. Hall (1992) indicated that teachers' perceptions about their own ability as well as the students' ability has an effect on the student's perceived self-efficacy. Early

anecdotal evidence on scientists and teachers involved in the GAVRT program indicates that their own level of efficacy is a determining factor in the success of the program. Other studies found that if the instructor has a high degree of personal teacher efficacy, then the students will have enhanced motivation (Ashton & Webb, 1986; Midgely, Feldlaufer, & Webb, 1989; Roeser, Arbreton & Anderman, 1993), higher self-esteem (Borton, 1991), and more positive attitudes toward school (Miskel, McDonald, & Bloom, 1983).

Method

The GAVRT Student Efficacy Survey included attitudinal questions about students' perceptions of science and their role in the scientific community. The survey was administered to seventh through twelfth grade students nationwide who participated in the Jupiter Quest program during the 2000-2001 and 2001-2002 school years and had 480 and 562 respondents respectively. Jupiter Quest is a curriculum component of the GAVRT program centered on the study of Jupiter's radiation belts.

The students completed a pre-survey prior to beginning the Jupiter Quest program and then completed a follow-up survey immediately after working on the Jupiter Quest program. During the period between the completion of the pre- and post-surveys, students worked with the radio telescope with mission control operators.

The efficacy survey was revised each year to increase the reliability of the results. The question "I like science" was added to the survey in 2001-2002. The question "I can complete a long-term scientific task" was eliminated from the 2001-2002 survey and replaced with "I am able to collect data using sophisticated scientific equipment" and "I am trusted when it comes to using sophisticated scientific equipment" because the scientists

and teachers in the program felt it could be an important factor in the students' feelings of efficacy. The question "I contribute to the work of other scientists" was eliminated from the 2002 survey. The wording of other questions was modified slightly to make them more easily understandable to students, in which case the essence of the question remained the same.

The instrument was created using information from other efficacy scales. In particular, a writing efficacy study (Klassen, 2001) that included an analysis of sixteen studies in which the measure of self-efficacy was identified as a reference point. In this study, fourteen of the sixteen measures were based on self-reports with the number of items per instrument ranging between four and ten. The scientific efficacy survey was also used in a scientific inquiry study that was conducted during the same time frame at the Lewis Center for Educational Research.

Results

Based on the results of the pre- and post-surveys, students who participate in the Jupiter Quest program generally exhibit an increase in their feelings of scientific efficacy (See Table). An area of efficacy that increased during both years of the study was the perceived value students attached to their work. During the 2000-2001 school year, students expressed an increase in their feelings of efficacy associated with the value they placed on the work they produced in science, $t(547) = 1.983, p = .048$. In the 2001-2002 school year, students again expressed an increase in the value of their work, this time as they felt other scientists value it, $t(437) = 3.288, p = .001$. An area that had a significant decrease in the 2000-2001 year was the effect of student's perceived ability to debate scientific topics, $t(554) = -2.510, p = .012$. The students were not clear about what this

Table

Student Scientific Efficacy *t* tests

Survey Questions	2000-2001 School Year	2001-2002 School Year
I like science		
t	-	1.175
p	-	.241
I can think scientifically		
t	.225	2.562**
p	.822	.011
I am able to use scientific equipment		
t	-	2.828**
p	-	.005
I can be trusted while using scientific equipment		
t	-	-2.058*
p	-	.041
I am comfortable asking scientists questions		
t	-2.510**	.719
p	.012	.473
I value my work as a scientist		
t	1.983*	-.202
p	.048	.840
Other people value my work as a scientist		
t	-.190	3.288**
p	.849	.001
I am able to find patterns or trends in data		
t	-.251	.579
p	.802	.563
I can rethink my ideas based on new information		
t	.119	-.108
p	.905	.914
I can complete a long-term project		
t	.880	-
p	.379	-

Note. The following questions were modified between the 2000 - 2001 school year and the 2001 - 2002 school year: "I am able to debate scientific topics" became "I am comfortable asking scientists questions," "I am able to draw conclusions" became "I am able to find patterns and trends in data", and "I am able to draw conclusions" became "I am able to rethink my ideas based on new information."
*$p < .05$ **$p < .01$

question meant and therefore this question was reworded for the second year of the study. No significant differences were found during the second year.

During the 2001-2002 school year, the effect of student's perceived ability to use scientific equipment increased, $t(437) = 2.828, p = .005$, as well as their ability to think scientifically increased after participation in GAVRT, $t(437) = 2.562, p = .011$. Students' feelings about being trusted to use sophisticated equipment significantly decreased, $t(437) = -2.058, p = .041$. It is not completely clear why the students' feelings about being trusted with sophisticated equipment decreased while their confidence in their ability to use it increased. It is possible that once students are comfortable using the equipment they are more confident and are likely to experiment with it. As a result, they feel that they have a much higher chance of hurting or breaking the equipment and feel that they are less trustworthy using it.

Discussion

The process of developing self-efficacy includes selecting, weighting and integrating information from a variety of sources. Findings from the GAVRT study indicate that participation in the program involves this process and promotes positive efficacy appraisals among middle and high school students. Students are given a variety of tasks and opportunities to perform, thereby providing a large menu of activities to choose from for use as part of their own development of efficacy. The process of weighting the importance of an activity as part of the efficacy process is naturally embedded in the GAVRT program, as students are well aware of the fact that they are operating multi-million dollar equipment and that the data collected will be utilized by top-level scientists from NASA and JPL. Students integrate and personalize their participation in GAVRT in a real-time situation

while on the internet or telephone line with the mission control operators and scientists. Immediate feedback from these adults enables students to more quickly assimilate the experience and apply its meaningfulness to their own lives.

Measures were taken to insure that the survey was administered in a standardized way, however, it is acknowledged that due to the national dispersion of participants, the classroom instructors were relied on to administer the survey as directed. Other limitations to the study included the fact that the survey was a self-report from only the student's perspective. The survey could be improved by adding a section for open-ended questions and comments.

The differences in the results between the two years could be accounted for by the fact that the respondents had widely different socio-economic statuses. In the 2000-2001 school year, 98.4% of the respondents were from schools with between 33 and 56 percent of the students on the free and reduced lunch program. In the 2001-2002 school year, 98% of the respondents were from schools with less than 18 percent of the students on free and reduced lunch. Another factor that could have affected the results is that more teachers of students in the 2001-2002 school year were teaching the GAVRT program for the second or third time. In the 2000-2001 school year, many teachers were teaching the GAVRT program for the first time.

Bandura's belief that a school's collective sense of efficacy predicts the school's level of academic achievement supports the aims of the GAVRT program. The GAVRT program can provide schools with a team of scientists and educators who can contribute to the positive efficacious feelings of a school. This could result in increased levels of academic performance as well as a better understanding of the role and functions of the

scientific community. With the current push towards measuring student achievement via standardized test measurements, it is increasingly important to recognize that there are a variety of ways in which student performance can be increased.

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